Building the Bioengineering Experience for Science Teachers (BEST) Program (Work in Progress, Diversity)

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INTRODUCTION

With the release of the Next Generation Science Standards (NGSS) in 2013, the teaching of science aims to more deeply connect engineering design and practice with science concepts using inquiry-based methods. The framework relates science to students' everyday lives, ensures students learn about being careful consumers of scientific and technological information, and prepares them with the skills to enter careers in science, engineering, and technology. Curriculum must harmoniously integrate the three dimensions of science learning highlighted by NGSS: core ideas, science and engineering practices, and cross-cutting concepts. While the core ideas are similar to past standards, the emphasis on students' understanding of the approach and methods employed by engineers and scientists, and the demand that engineering and technology be integrated into the structure of science education by "raising engineering design to the same level as scientific inquiry" [1] presents new challenges for science teachers. While teachers generally support higher standards and effective instruction, few have the opportunity to develop their content knowledge and pedagogical skills in ways that translate into classroom practice. Summer research experience programs aim to build long-term collaborative partnerships with STEM teachers by involving them in research and introducing them to the most current developments in engineering and science. Opportunities for high school science and pre-engineering teachers to participate in bioengineering research projects provides professional development, improved understanding of scientific and engineering principles, broader dissemination of the discipline to the teacher's peers, and can also encourage and motivate his or her students to pursue careers in bioengineering. To ensure these outcomes, it is critical to support the translation of their experience to their own classrooms in ways that will meaningfully impact their students' learning.

Professional development (PD) is an important way for teachers to deepen their content knowledge and keep informed of current best practices in teaching. However, in a study of over 1,000 teachers, Garet, *et.al.* determined that many PD activities that teachers participate in do not contain features representative of high-quality professional development. These core features are deepening content knowledge, promotion of active learning, fostering coherence, perceived enhancement of knowledge and skills, and influence in teachers' classroom teaching practice [2]. Their results suggest that sustained and intensive professional development that focuses on specific academic subject matter, coupled with planning for classroom implementation and alignment with national and state standards is more likely to produce enhanced knowledge and skills.

This paper discusses the evolution of the Bioengineering Experience for Science Teachers (BEST) Program at the University of Illinois at Chicago (UIC). As the largest urban public research institute in Chicago, our Research 1 university is proud to serve an extremely diverse student population, where there is no racial majority. With a focus on urban environments, the University of Illinois College of Education aims to improve the educational outcomes for African American and Latino students by preparing educators to work in the Chicago Public School District (CPS), who are committed to education equity for all students. Today, 1 in 7 students in CPS is taught by a UIC College of Education trained teacher

[3]. As an extension of the University's commitment to diversity, the BEST program was designed to engage teachers who teach specifically in CPS, the third largest district in the country. The goal of this College of Engineering and College of Education collaborative summer research experience is to enhance the skills of CPS science teachers and enable them to more effectively communicate the nature of the scientific process in bioengineering to their students. BEST Teacher Fellows have a meaningful summer research experience in a bioengineering laboratory working on a well-defined project and use this first-hand experience to develop curricula that translates their scientific knowledge into specific curriculum maps, instructional materials, and classroom assessments that are aligned with NGSS [4-7].

METHODS/PROCEDURE

The program recruits up to 8 high school science teachers each year through targeted emails to all district science teachers from the CPS Department of Science, notices sent to school principals, as well as through the BEST website [8]. Applicants were required to submit a CV, letter of recommendation, a sample curriculum, and statement of interest with their application. In addition, interested teachers selected their preference for research laboratories as they aligned with their interests. Teachers were chosen on the strength of their application with consideration given to type (neighborhood, magnet, selective enrollment), geographic diversity, and student demographic of the school in which they teach. BEST Teacher Fellows each receive $7,500 stipend and $1,000 allotment for classroom materials to implement their bioengineering curriculum at the end of this full-time six-week program. In addition, Fellows receive an additional $500 following the completion of a post-curriculum implementation survey in December. Prior to the start of the program, selected participants meet program directors (faculty from the Departments of Bioengineering and Curriculum and Instruction) in a three-hour evening spring kickoff session. At this meeting, BEST Teacher Fellows have an introduction to the University, the BEST program, one another, and the field of bio(medical)engineering. Fellows complete paperwork required for campus internet, building access, as well as safety and lab equipment training and a pre-program survey. Fellows are also provided recent publications written by the bioengineering faculty mentor from the lab in which they will be working. Finally, BEST Teacher Fellows are advised on the nature of research, acknowledging the "deep dive" they have committed to for professional development.

The BEST Program is structured such that Fellows are in the bioengineering research laboratories each day from Monday through Thursday. During this time, Teacher Fellows learn about the work being undertaken in each lab and develop their own project work in collaboration with postdocs and graduate students under the guidance of their faculty mentor. Each Friday, the BEST cohort of Fellows meet with program leaders, together forming a *community of practice*, in which they share and discuss their lab experiences and brainstorm ways to develop appropriate curriculum in alignment with NGSS standards. These workshops are an opportunity for Teacher Fellows to develop curriculum related to their summer research experience, with guided instruction from faculty who have knowledge in Common Core State Standards, Next Generation Science Standards, and curriculum design. Each week, Fellows also complete a progress survey that asks about their knowledge base on bioengineering content and curriculum design. On the last day of the program, CPS administrators, school principals, bioengineering lab members, and family are invited to presentations by each BEST Fellow on their experience and their curriculum development. Following the program conclusion, the curriculum frameworks that each Teacher Fellow developed, including rubrics ,instructional materials, and

student assessments, are uploaded to the online Curriculum Library on the BEST program website [8] for public dissemination.

This study is a mixed-methods descriptive study, employing surveys with both closed and open-ended questions to discover and note trends of what aspects of the program have a positive impact on teacher participants' development of depth of content knowledge and pedagogical skills. This study specifically focuses on the following research question: What impact does the BEST program have on teacher fellows' depth of content knowledge and pedagogical skills? Utilizing both quantitative and qualitative data can provide a better understanding of how teacher fellows developed depth of content knowledge and pedagogical skills than either method alone could have done [9]. The underlying principle of combining both qualitative and quantitative data is that neither method alone is adequate to fully answer the research question [10]. When quantitative and qualitative methods are used in combination, research can benefit from the strengths of both methods and have a deeper analysis [11-13].

Program orientation included description of research procedures and participation in the study. Participants who agreed to participate in the research component completed a pre-survey on Qualtrics. This survey serves as a baseline of teacher fellows' depth of content knowledge and pedagogical skills in bioengineering and educational practices. At the conclusion of each week of the program, teacher fellows completed a survey on Qualtrics to evaluate their weekly experience in their research lab and educational workshop. These weekly surveys were designed to examine the aspects of the RET program that give teacher fellows the opportunity to develop their depth of content knowledge and pedagogical skills. They further examine any barriers, obstacles, and supports that exist that impeded or support teacher fellows' ability to develop their knowledge and skills. The survey was designed with a combination of both closed-ended and open-ended responses. The closed responses will allow for statistical analysis while the open-ended responses will allow teacher fellows to respond to questions in their own words and to encourage a greater depth of response [10]. The closed ended responses are in 5-point Likert format, designed to assess teachers' knowledge and skills in bioengineering and educational practices. The open-ended responses provide the opportunity for teacher fellows to include more in-depth answers. All surveys will be developed using a UIC Qualtrics account for survey administration and analysis. On the final day of the summer program, teacher fellows completed another survey on Qualtrics that serves as a comparison to the pre-survey that they completed prior to the commencement of the BEST program. This survey was designed to examine growth in teacher fellows' depth of content knowledge and pedagogical skills in bioengineering and educational practices.

RESULTS

By advertising our program through the Chicago Public School District's Department of Science, the program received 20 applications from CPS high school teachers, teaching classes ranging from Forensic Science, Biotechnology, Introduction to Engineering Design, Principles of Engineering, as well as the more general science courses such as chemistry, physics, and biology. We note an increased number of applicants with a more direct connection to teaching engineering-type courses at the high school level apply relative to past years (6/20, 30%). A program priority is to recruit a diverse group of teachers that work at a variety of schools across the district, to serve a diverse student audience spanning the geography of the city. In an effort to recruit a diverse population of teachers teaching in a diverse mix of schools, we chose applicants

from a math & science academy, career academy, a magnet school, and neighborhood high schools throughout the Chicago area. Participants in the 2019 program were seven CPS teachers, including three males and four females, with a range of teaching experience from 1 to 17 years (average 5.6 years). The teacher fellows included two Asian, 2 Black, 2 White and 1 teacher who chose not to respond.

At the conclusion of each week of the program, teacher fellows completed a survey in Qualtrics to evaluate their weekly experience in their research lab and educational workshop. All surveys were developed using a university Qualtrics account for survey administration and analysis. The principal investigators used Dedoose.com to conduct a qualitative thematic analysis of data. Data trends in the surveys indicate that teachers had an overall high perception of their experience in the BEST program, but also highlighted some aspects that hindered their ability to develop content knowledge and pedagogical skills. When asked about aspects of the program that promoted their ability to develop content knowledge and pedagogical skills, three key themes emerge: the importance of collaboration, background research and time to develop curricula, and ongoing feedback.

The BEST program continues a partnership with the High School Science Specialist in the CPS Department of Science Education. This role supports all high school science teachers within the district. The High School Specialist helps to facilitate recruitment efforts, participates in our program orientation, provides valuable program input and feedback, and evaluates teachers' final presentations. Leadership from the Department of Science Education join the final presentations at the end of the program. Select data from a survey post-implementation with the **2018 BEST Fellow** respondents (surveyed in December 2018, n=5/7) is shown in Table 1. Select free responses to survey questions included below.

What aspects of your lab experience promoted your understanding of bioengineering?

- I'm highly encouraged to participate in the actual research, instead of my prior experience working in labs where I was essentially just doing the gruntwork every day. Here I have a lot of freedom to take the research and design work in whatever direction I want to, which has been really cool and engaging.
- Similar to the previous week, I am very involved in the actual research of the lab, which has given me an opportunity to learn from experience what the field of bioengineering is actually like, instead of just learning about bioengineering.
- Dr. A had a great idea for my final project and provided some time to discuss these ideas and make it as transferable to the classroom as possible.
- I like being able to view the different projects the Bio-engineers and undergrads are working on. I also like to hear their thought processes and how they turn their ideas into something tangible. Being able to discuss with my PI about possible labs and experiments I can implement in my classroom with the experiments I am doing in the lab.
- I presented at the round table that happens every Wednesday. I enjoyed this because not only was I able to share a little about what I have been working on, but I also received suggestions from the team about ways to incorporate engineering in my classroom. I also was able to share some of the things I do in my classroom and a few of my instructional approaches that keeps students actively engaged even during lecture.
- I had a bit of an equipment failure, which honestly prepared me for leaving room for that sort of stuff in my schedule during the year, and is likely something I should prepare my students for as well.

What was the highlight of your lab experience this week?

- I made a suggestion for improvement of the design of a device I was testing which was approved, so am now working on probably the 4th iteration of the design to improve ease of use. I've been getting a lot of experience with Solidworks and 3D printing as well, which if I get a 3D printer for my classroom would obviously prove to be helpful.
- I was able to "split and passage" my cells all by myself! I have been keeping a culture of fibroblasts cells alive and every 3 days they need to be transferred to another container to have more room to grow. I felt really good about learning a lab technique in just a few days and being able to execute it by myself.
- My conversation with Dr. X about instructional approaches and attention span was my highlight this week. It was nice being able to contribute instructional ideas to a professor/biomedical engineer who is so well-renowned and brilliant.
- We started a new experiment, and I am able to repeat many of the techniques that I learned at the beginning of the program, but now more independently. It is rewarding to feel like I am able to learn new skills in so little time.

What was the highlight of the curriculum workshop this week?

- I really enjoyed the share outs. I was given a lot of suggestions as to how I can implement some of my experiences in the lab within my classroom without actually having my students coding.
- Same as the learning aspects - talking with other teachers from different backgrounds with different approaches is SUPER enlightening on my own practice.
- Hearing the ideas and reviewing the curriculum of others allowed me to see where my curriculum has great success and where it needs improvement.
- Brainstorming other teacher's ideas - it's good to get a productive brain break from my own stuff. Bouncing ideas for my curriculum and implementing streamlining as a result.
- I really like being able to express what I am struggling with and hearing the suggestions and advice of everyone.
- It was really helpful to see each other curriculum this week. Working with teachers who have a lot more experience than me has been very motivating. I was so impressed to see the level of detail in their curriculum planning.

What specific successes did you experience with teaching your BEST curriculum?

- Students really enjoyed the hands-on nature of the summative part of the unit (constructing the timed-release device).
- Some students have found their new niche and want to become engineers! It has even helped some students with motivation to attend school and not drop out. Students confidence levels with technology has increased as well.
- The students liked the challenge of making a sensor that could detect unseen objects in a "sample" they also made. They also like the freedom of picking a topic that was related to Electromagnetic Induction.
- The primary success this year was teaching my students how to use molecular architecture applications such as molView, WebMo, and Avogadro.

What components of the BEST program were the most beneficial in implementing your curriculum?

- Next Generation Science Standards make teaching physics difficult and if not for UIC BEST program my administration would not have allowed me to do this unit.

- The most important here was my exposure to the Engineering practices, which made it much easier to have those conversations with my students.
- Being able to experience the process myself and having the opportunity to design the experiments for my students.

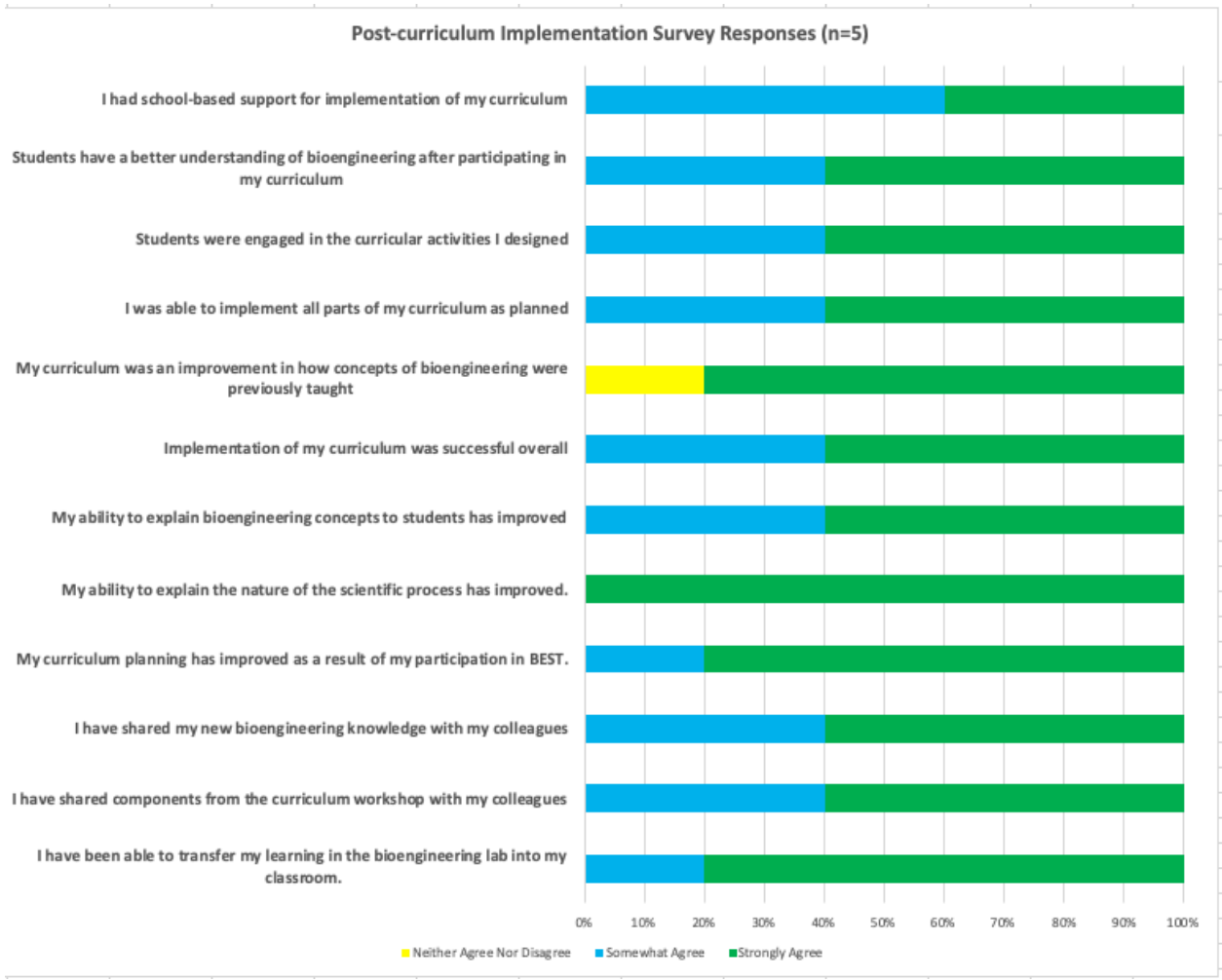

Table 1. Follow up survey data from Dec 2018-May 2018 (six months+ post-summer program), after BEST Fellows have implemented the curriculum in their classrooms.

DISCUSSION

The BEST program addresses three forms of content which have been shown to be connected to improvements in teacher practice. (1) BEST supports teacher learning of bioengineering subject matter generally and content related to teachers' lab placement specifically. Additionally, (2) teachers are offered instruction in teaching methods and pedagogical approaches which facilitate meeting the inquiry and engineering design requirements detailed in the NGSS. Lastly, (3) BEST provides teacher support specific to the planning and development of a NGSS, engineering design focused unit plan. The BEST program faculty recognize that effective STEM instruction and integration relies on a teacher's self-efficacy [14]. Because of this multi-prong approach to the content aspect of the conceptual

framework that we focus here on teachers' self-efficacy and perceptions of the 2019 program's impact on their content knowledge and pedagogical skills.

Positive outcomes: One Teacher Fellow is on the 2021 planning committee for the National Association of Research in Science Teaching and has submitted a proposal for past BEST Teachers to lead a workshop/panel to share their experience with the BEST program to other science teachers. Several bioengineering undergraduate students were connected to the Chicago Public School Robotics competition and will serve as judges. Several Fellows have partnered with the Bioengineering Faculty Mentors to have student field trips to their research labs.

Challenges: The 2019 summer BEST program was in all senses a success. Teachers reported very positive feedback. In addition, bioengineering faculty reported strong support for the program to continue. This year we have begun preparing two manuscripts to describe and report our progress in the BEST program. In addition, we have been reflecting on ways to deepen our understanding of the program impact on teachers as well as their classrooms. As we consider a renewal application, we are defining ways to strengthen and analyze the program more rigorously.

CONCLUSION

Reflecting on the progress made through the end of year 4 of this grant support, we are confident that the BEST program is having a positive impact on its participants. We continue to recognize the importance of fostering strong collaboration between the BEST Fellows to support one another's curriculum design by collectively working to identify connections between lab experiences and NGSS standards. Directed sessions emphasized lesson planning, using intrinsic motivation and culturally relevant pedagogy to create relevant lesson plans, differentiation and tiering to create lessons for all learnings, assessments to promote learning, checking for understanding and asking effective questions – using their bioengineering lab research experiences as the content. An additional aspect of the program that teacher feedback has repeatedly pointed to is the importance of teachers experiencing themselves the "dead ends" or failures that are inherent in scientific research. Teachers have brought up the value of being able to speak to these issues in supporting the concept of resiliency in their own students. As we continue to improve and refine the program, we are interested in gathering stronger data to explore how these concepts are transferred to classrooms and if they indeed promote increased learning and interest in bioengineering.

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